ASTROBIOLOGICAL POTENTIAL OF ROCKS ACQUIRED BY THE PERSEVERANCE ROVER AT THE FRONT OF THE WESTERN SEDIMENT FAN IN JEZERO CRATER, MARS. T. Bosak[1], D. L. Shuster[2], B. P. Weiss[1], L. E. Mayhew[3], E. L. Scheller[1], S. Siljeström[4], K. A. Farley[5], K. M. Stack[5], A. Brown[6], C. D. K. Herd[7], K. Hickman-Lewis[8], J. Nunez[5], J. I. Simon[9], J. Bell III[10], K. C. Benison[11], M. Wadhwa[10], A. J. Williams[12], [1]Massachusetts Institute of Technology, Cambridge, MA, [2] University of California, Berkeley, Berkeley, CA, [3]University of Colorado, Boulder, CO, [4]RISE Research Institutes of Sweden, Stockholm, Sweden, [5]Jet Propulsion Laboratory, Pasadena, CA, [6]Plancius Research, MD, [7]University of Alberta, Edmonton, AB, Canada, [8]Natural History Museum, London, UK, [9]Lunar and Planetary Institute (USRA), Houston TX, [10]Arizona State University, Tempe, AZ, USA, [11]West Virginia University, Morgantown, WV, [12]University of Florida, Gainesville, FL

Introduction: Major objectives of the Perseverance rover mission include identifying past habitable environments, collecting rocks that are likely to preserve biosignatures and using the rover's instruments to look for potential biosignatures in these rocks [1]. The recognition of the > 3.5 billion-year old habitable environments in Jezero crater, Mars (**Fig. 1**; [2-4]) promised that the mission could achieve these objectives [1]. The western sedimentary fan deposit, the hydrated minerals therein and the carbonate minerals at the margin of this fan were identified as particularly compelling areas in which to search for the signs of past life and collect the oldest aqueously deposited rocks from another planet [1, 4].

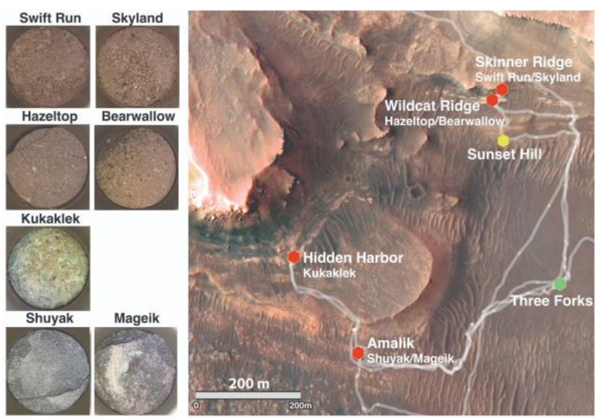

***Figure 1. Rock cores collected at the front of the western Jezero fan during the Fan Front Campaign*.** CacheCam images of the cores in their container tubes are on the left. Red symbols on the High Resolution Imaging Experiment (HiRISE) map in the right show the locations of the sampled outcrops and the corresponding cores. All cores are 13 mm in diameter. White lines on the map delineate the rover's trajectory during the Fan Front Campaign. Green symbol shows the location of the Three Forks Cache.

Neither rover-derived datasets nor the currently available Martian meteorites allow comprehensive reconstructions of past Martian habitability, climate and potential biosignatures. Thus, the scientific community has prioritized the return of martian rock samples with known geologic context for at least a decade [5]. Having collected eight rock samples from the igneous floor of Jezero [6], the rover acquired seven samples of aqueously deposited sedimentary rocks from the front of Jezero fan (**Fig. 1**). A subset of these fifteen rock cores, regolith samples and witness tubes was placed at Three Forks (**Fig. 1**). Here, we describe the samples collected at the fan front and discuss their astrobiological potentials.

Stratigraphy and Sedimentology:

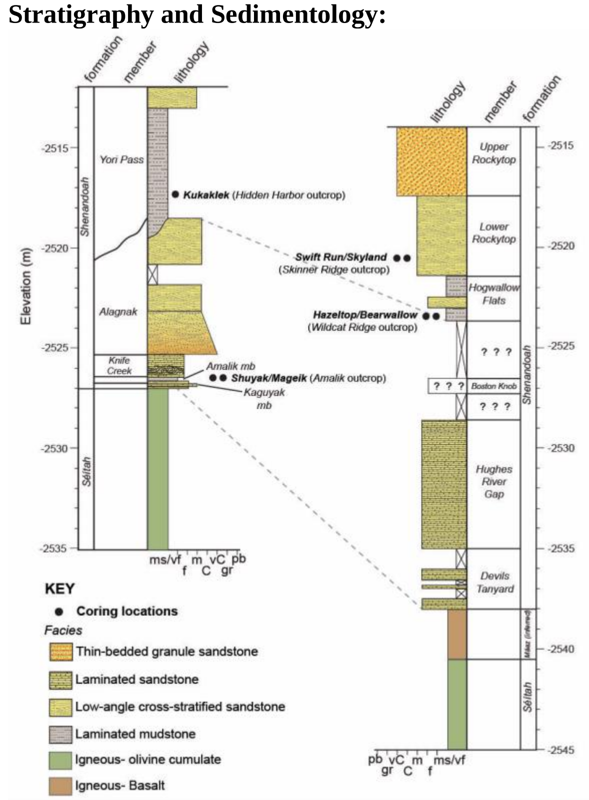

Figure 2: Stratigraphy of the fan front deposits in the Shenandoah formation including the sampled outcrops. Black circles indicate coring locations. Left column: stratigraphy in the western part of the fan front examined by the rover. Right column: stratigraphy at the fan front closer to the ascent path of the rover up the fan front. Pb = pebble; gv = granule; vC = very coarse sandstone, C = coarse sandstone, m = medium sandstone, f = fine sandstone, ms/vf = very fine sand; mb = member.

All collected samples from Jezero fan front have a well-constrained geologic context (**Figs. 1, 2).** The outcrop, bed and grain-size analyses support the interpretation of these samples as deposited by water in

environments that are interpreted to have transitioned from fluvial to lacustrine and deltaic [7].

The *Swift Run* and the *Skyland* cores (**Figs. 1, 2**) fulfilled the desired characteristics for the coarse-grained sediment sample from a stratigraphically higher position on the fan front. These cores contain a heterogeneous population of detrital materials deposited into the fan, including grains that may have originated outside of Jezero crater, sand-sized or larger grains that enable geochronology, as well as any aqueously precipitated minerals such as carbonates, sulfates or clay minerals.

The *Hazeltop* and the *Bearwallow* cores are fine-grained sedimentary rocks from a relatively low stratigraphic position (**Fig. 2**). The single *Kukaklek* core was collected from *Hidden Harbor*, a coarser-grained lateral equivalent of *Wildcat Ridge* at *Yori Pass* (**Fig. 2;** [7]).

At *Amalik*, Perseverance acquired the *Shuyak* and the *Mageik* cores. *Shuyak* and *Mageik* fulfill the desired characteristics for an aqueously deposited sedimentary rock sample from a low stratigraphic position at the fan front (**Fig. 2**).

Sample Documentation: Upon successful sampling, the Science Team processes the instrument data and uses the information to write Initial Reports. These reports summarize the sample lithologies and compositions, their geologic and stratigraphic context, and rationale for sampling and are available publicly at the NASA Planetary Data System (PDS) at https://pds-geosciences.wustl.edu/missions/mars2020/returned_sample_science.html

Sample Composition: All rocks sampled at Jezero fan front are hydrated and contain clay minerals with different compositions [10]. Additional minerals produced by aqueous alteration or by precipitation from solution vary among the different outcrops. *Bearwallow*/*Hazeltop* and *Kukaklek* contain up to ~ 20 wt% of SO_3 in sulfate minerals and some anhydrite, whereas *Skyland/Swift Run* and *Shuyak/Mageik* contain Fe/Mg carbonate minerals. The sulfate minerals in the matrix of *Bearwallow*/*Hazeltop* and *Kukaklek* are hydrated, exhibit a Fe+Mg+Mn/S =1 ratio and lack Al, so they are likely hydrated sulfates that contain ferrous iron and magnesium as the major cations. Anhydrous sulfate minerals occur in *Shuyak/Mageik*. Anhydrite occurs in the white veins and the lightest grains in *Bearwallow*/*Hazeltop* and *Kukaklek*. The abundance of elements that are not quantifiable by PIXL, such as H, C and N, and water is the highest in *Skyland/Swift Run* and the lowest in the sulfate-rich cores. Minor phases such as Fe-Ti oxides, phosphate, zircon/baddeleyite and Fe-Cr oxides detected in *Skyland/Swift Run* and *Shuyak/Mageik* can enable geochronological, paleomagnetic and provenance studies of returned materials. The likely inorganic sources of UV luminescence and the absence of G-bands from the Raman spectra of all abraded patches indicate that organic concentrations are lower than ~ 0.1 wt% [10]. The time-integrated doses of ionizing radiation experienced by the sampled rocks allow for the preservation of organic compounds and textural biosignatures [11].

Astrobiological Potential: The *Hazeltop* and *Bearwallow* samples have the highest astrobiological potential due to their small grain sizes, the abundance of clay minerals and sulfate minerals that can trap various fluids and organic inclusions [12]. The *Kukaklek* core also contains precipitated sulfate minerals and clays, but it has a lower astrobiological potential relative to the *Hazeltop* and *Bearwallow* cores because of more pervasive evidence for later fluid flow that is not conducive to organic preservation.

The coarser-grained mudstones and sandstones such as *Shuyak/Mageik* and *Skyland*/*Swift Run* are less than ideal for organic and biosignature preservation, but contain carbonate minerals and detrital grains that are key to constraining the weathering processes in the watershed and on the fan, reconstructing the history of martian climate and volatiles and quantifying the timing and duration of aqueous activity in the fan.

Implications for the Return Sample Science: Aqueously deposited and altered rocks from known locations and with a well-constrained geological context in Jezero crater have the potential to preserve organic matter and potential biosignatures. Analyses of the returned materials in terrestrial laboratories would also provide the currently unavailable organic, isotopic, chemical, morphological, geochronological and paleomagnetic records of the coupled evolution of Mars's water, carbon, redox and climate cycles.

References:

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